

Technical Procedures Bulletin

**Subject: A National Radar
Reflectivity Mosaic from WSR-
88D Radar Coded Messages**

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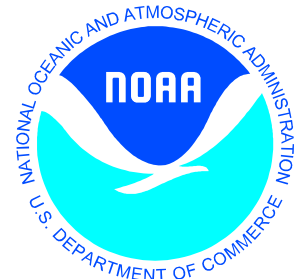
Abstract:

This Technical Procedures Bulletin was written by David H. Kitzmiller and Frederick G. Samplatsky of the Meteorological Development Laboratory in the NWS Office of Science and Technology.

The TPB describes the source of data for the new mosaic, dimensions of the coverage, times of collection, and complications in using the data. Strategies used in the production including slicing of the intensity of the data, methods of removal of biological and other noise, terrain blockage, and missing data are described.



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A NATIONAL RADAR REFLECTIVITY MOSAIC FROM WSR-88D RADAR CODED MESSAGES

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1. INTRODUCTION

Weather surveillance radar is used extensively in short-range forecasting operations. It is often highly desirable to view the observations of several radars simultaneously, even for local forecasting operations, in order to monitor the development and movement of synoptic-scale systems or to get the best possible observations of small-scale features which are distant from the local radar.

The National Weather Service (NWS) implemented some radar mosaicking techniques as early as the 1960's. These mosaic operations were based on collection and compositing of manually-digitized information transmitted from individual radar sites as Radar Observations (ROBs) (Sadowski 1979; Departments of Commerce and Defense 1980). A Manually-Digitized Radar (MDR) mosaic with approximately 40-km grid spacing was created by compositing echo location and intensity data contained in the ROBs.

With the deployment of the WSR-88D network, the manually-produced ROB was replaced by the automatically-produced Radar Coded Message (RCM). The RCM contains information on echoes within the local portion of a national 10-km reflectivity grid, a description of convective echoes including maximum reflectivity, echo tops and mesocyclone phenomena, and the local Velocity-Azimuth Display Wind Profile (OFCM 1991).

The first software suite for the production of a national reflectivity mosaic from RCMs was implemented within the NWS National Centers for Environmental Prediction (NCEP), at the Aviation Weather Center (Lewis and Mosher 1992; Cope 1993). The mosaic was produced as an interim step in a process that created automated Radar Observations that duplicated the historic ROB format, and the mosaic itself was not disseminated in digital form. This suite relied on communications systems and proprietary system software due to be eliminated with the introduction of the Advanced Weather Interactive Processing System (AWIPS). Accordingly, it was decided to rehost the software within NWS Telecommunications Operations Center, on hardware that had been in use there for several years.

A complete description of the mosaic and its production is contained in Kitzmiller et al (2002).

2. INPUT RADAR DATA

The RCM (OFCM 1991) contains a coded text description of the local portion of a national reflectivity mosaic grid, a coded description of convective storm cells within the local radar umbrella, and a Velocity-Azimuth Display (VAD) wind profile based on Doppler information. In the reflectivity grid portion of the RCM, lines of text contain the starting row and column position of runs of nonzero reflectivity levels (1-8) observed along rows within the grid. These reflectivities are derived from the Digital Hybrid Scan (DHS) reflectivity array (Fulton et al. 1998), which is also used to derive

precipitation accumulation estimates. The RCMs are produced twice per hour, roughly in the intervals 00:05-00:15 and 00:35-00:45, and are centrally collected on a file server at NWS headquarters.

The DHS algorithm incorporates quality control procedures that effectively reduce or eliminate ground clutter, anomalous propagation, and single-grid-box echoes sometimes referred to as 'shot noise'. However, significant non-precipitation features sometimes remain in the RCM's, with calibration test patterns appearing on rare occasions, AP appearing occasionally, and returns from biological targets (birds and insects) being common from late winter through late autumn.

3. THE RADAR REFLECTIVITY MOSAIC

The mosaic is projected on a polar stereographic grid with the following characteristics:

Orientation: 105°W (255°E)
Reference latitude: 60°N
Mesh length at reference latitude: 11906.25 m
Extreme lower-left corner position: 119.036°W, 23.097°N
Extreme upper-right corner position: 58.025°W, 45.317°N
Number of rows: 360
Number of columns: 460

This grid is coaligned with the MDR grid and the Hydrologic Research and Applications Program (HRAP) grid, which have reference mesh lengths of 47625 m and 4762.5 m, respectively.

Note that our convention is that grid position (1,1) is at the lower-left corner of the lower-left box; thus continuous grid position values ≥ 1 and < 2 are within box 1, position values between 2 and 3 are within box 2, etc.

The reflectivity data within the grid describe the largest value observed within the box. The reflectivity values are coded as follows:

0: < 15 dBZ	4: 45-49 dBZ
1: 15-29 dBZ	5: 50-54 dBZ
2: 30-39 dBZ	6: ≥ 55 dBZ
3: 40-44 dBZ	7: No coverage or degraded coverage.

A value of 7 is placed in grid boxes that lack coverage from any radar, due to permanent gaps in network coverage, temporary gaps due to nonreporting radars, or subregions within radar umbrellas that are seriously occulted (blocked from the radar's view) by terrain features. Note that the RCM's themselves contain values of 7 and 8 to describe echoes beyond 230 km from the radar; these indicate echoes of indeterminate reflectivity level and no attempt has been made to include them in the mosaic.

For grid boxes covered by multiple radars, the highest observed reflectivity is placed in the final composite. While it is sometimes considered desirable to assign the reflectivity observed by the closest radar to the box, the strategy we chose is the simplest to apply operationally, and insures continuous spatial coverage when some radars are temporarily out of commission, or when radar units are moved or installed. The 'highest observed reflectivity' method may sometimes introduce features such as elevated hail cores into the composite while the 'nearest radar' approach would not; however such features are of concern mainly when the aim is to produce rainfall estimates from the data. The primary purpose of this composite is to provide a synoptic overview, with an emphasis on identifying the location and approximate intensity of rainfall (National Weather Service 1992). It is not

intended for rainfall estimation, since the input reflectivity field has insufficient spatial and temporal resolution for such a purpose.

Sample reflectivity composites appear in Fig. 1 (national view) and Fig. 2 (regional view). The composites are produced twice per hour, and are available at about 00:05 (for RCMs from 00:45) and 00:35 (for RCMs from 00:15). They are disseminated in Gridded Binary (GRIB) format (Dey 1996; World Meteorological Organization 1988) under World Meteorological Organization header HAXA00 KWBC.

4. QUALITY CONTROL OF THE REFLECTIVITY FIELD

As noted above, nonprecipitation (NP) echoes are common in RCM reflectivity fields. The most common are those from biological targets (insects and migrating birds) and aircraft. Anomalous propagation does appear on occasion. Finally, radar calibration test patterns, which are transmitted from sites while an artificial radio signal is fed into the antenna's receiver horn, are sometimes transmitted inadvertently.

The presence of (NP) echoes in the RCM reflectivity makes some quality control (QC) necessary prior to dissemination of the mosaic. Comparison of unedited and manually-edited mosaics suggests that almost 50% of the echo area is due to NP targets at night during the spring and autumn bird migration seasons, about 20-30% are NP during summer, and about 15% are NP during winter.

Efforts at automatically detecting and removing NP echoes from radar products have generally been focused on high-reflectivity features such as terrain, GC, and AP (see, for example, Fulton et al. 1998; Grecu and Krajewski 2000), which have serious effects on rainfall estimates. The QC algorithms applied to the RCM reflectivity appear to have been very successful at removing such ground-target echoes. The remaining NP echoes in the RCM, while generally < 30 dBZ intensity, have a major impact on the visual representation of the overall echo field.

To eliminate test pattern echoes, we have adopted a convention whereby suspicious RCM's featuring echo coverage over almost their full 460-km coverage radius are excluded from further analysis. In order to eliminate biological and aircraft echoes, RCM grid boxes with nonzero echo levels are flagged for deletion if the local echo texture and reflectivity spectrum suggest biological rather than precipitation targets, if satellite and upper-air humidity observations indicate little potential for precipitation, or if there is a lack of spatial continuity in the echo field. Therefore three mosaic-editing processes are used to remove NP echoes: a bird/insect check, a cloud/humidity check, and a shot-noise filter. A final check identifies surface reports of precipitation, lightning observations, and radar echoes detected by multiple radars, all of which are events that tend to confirm precipitation. This final check locally overrides the results of the first three, by reinserting any echoes that are within five grid spaces of the confirming feature.

The various editing checks are described completely in Kitzmiller et al. (2002). A comparison of manual editing results and the full suite of automated editing checks was made based on a data sample collected during the period July 1999 - April 2000. Within this dependent sample of cases, the results agreed in about 90% of cases in the winter, and in 80-85% of cases during the remainder of the year. The most common error was retention of NP echoes, a bias we favor as being the more conservative alternative. In practice, few large spurious features appear in edited mosaics, and major precipitation features are rarely altered.

5. INDICATIONS OF MISSING RADAR COVERAGE

Although most places in the United States are within 230 km of one or more WSR-88D's, there are coverage gaps over sparsely-populated portions of the Great Basin and the Southwest. Also, some places within 230 km of only one radar are essentially uncovered because of beam blockage by terrain features. In addition to such permanent coverage gaps, temporary gaps appear in the vicinity of nonfunctioning or nonreporting radars. In Fig. 1, coverage gaps beyond 230 km from any radar exist over extreme northeastern Arizona and northwestern New Mexico; gaps due to occultation are evident to the west of Portland, Oregon, and south of Tucson, Arizona; a temporary coverage gap due to nonreporting radars appears over Maine, New Hampshire, and Vermont. We have adopted a convention of indicating these gaps as an aid in interpreting the movement and evolution of precipitation patterns in areas of degraded radar coverage.

To provide indications for the effects of beam blockage by terrain, we used occultation maps for each radar site from the NWS Radar Operations Center. The maps indicate the percentage of the radar beam that is blocked by terrain as a function of azimuth and range for each of the lowest four antenna elevation angles. These four scans are used to construct the DHS reflectivity product, from which precipitation accumulation and the RCM reflectivity are derived.

By comparing these maps to local echo climatologies we developed a convention for determining blockage in the RCM grid. A box is considered blocked with respect to a radar if either condition (a) or (b) apply:

- (a) the box is centered more than 100 km from the radar and more than 50% of the azimuth/range bins over the box are more than 55% occulted at the lowest antenna elevation;
- (b) more than 33% of the azimuth/range bins over the box are more than 55% occulted at both the first and second antenna elevation angles.

The blockage pattern surrounding each radar is applied to the local section of the mosaic when the radar's observations are incorporated. If the reflectivity level for a box is zero and the occultation map indicates that the box is blocked, a missing indicator is stored there. The indicator is cleared if another radar's observations cover the box.

Mosaic grid boxes left uncovered for any reason are described by a reflectivity code of 7. Note that this is different from the convention within RCM's, where 7 and 8 describe echoes beyond 230 km from the reporting radar.

6. GENERATION OF THE NCEP FACSIMILE RADAR SUMMARY CHART

Information from the radar mosaic is contained in a facsimile chart generated by NCEP. The reflectivity field is displayed in contoured form, with contour intervals set at reflectivity levels 1, 3, and 5. Information on the precipitation area and convective cell movement and echo tops is plotted in text format. The content of the chart is fully described by Sadowski (1979).

7. FUTURE WORK

Efforts are now underway to create higher-resolution mosaics of reflectivity, vertically-integrated liquid (VIL), rainfall, and other WSR-88D products. These mosaics will feature 16 intensity levels and can be generated at 2- and 4-km resolution several times per hour.

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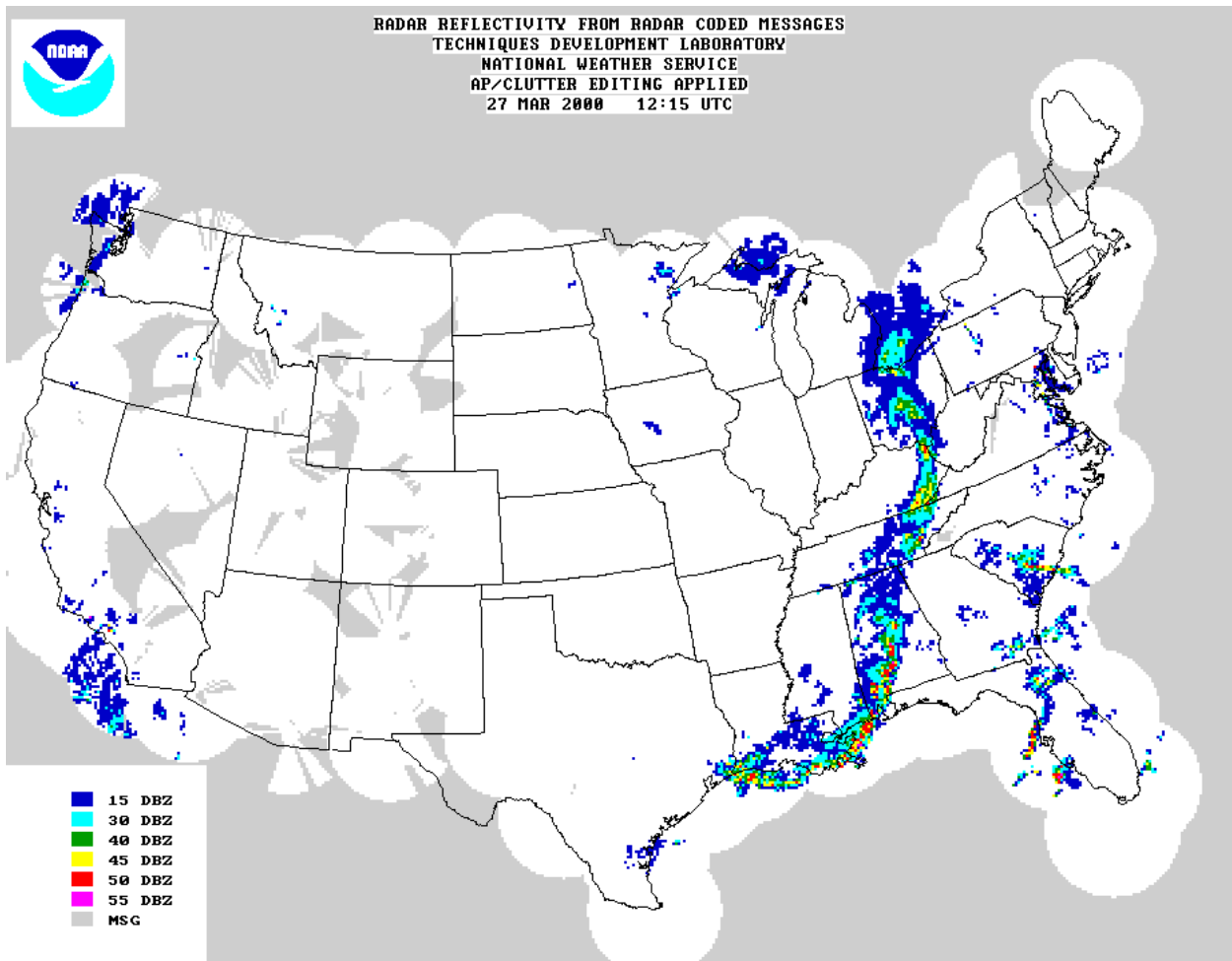


Figure 1. National 10-km radar composite from Radar Coded Messages, for 1215 UTC, 27 March 2000. Blank areas indicate reflectivity < 15 dBZ, light gray indicates areas beyond 230 km from the nearest radar, or areas blocked from the radar network by terrain. Precipitation reflectivity levels are indicated in the legend.

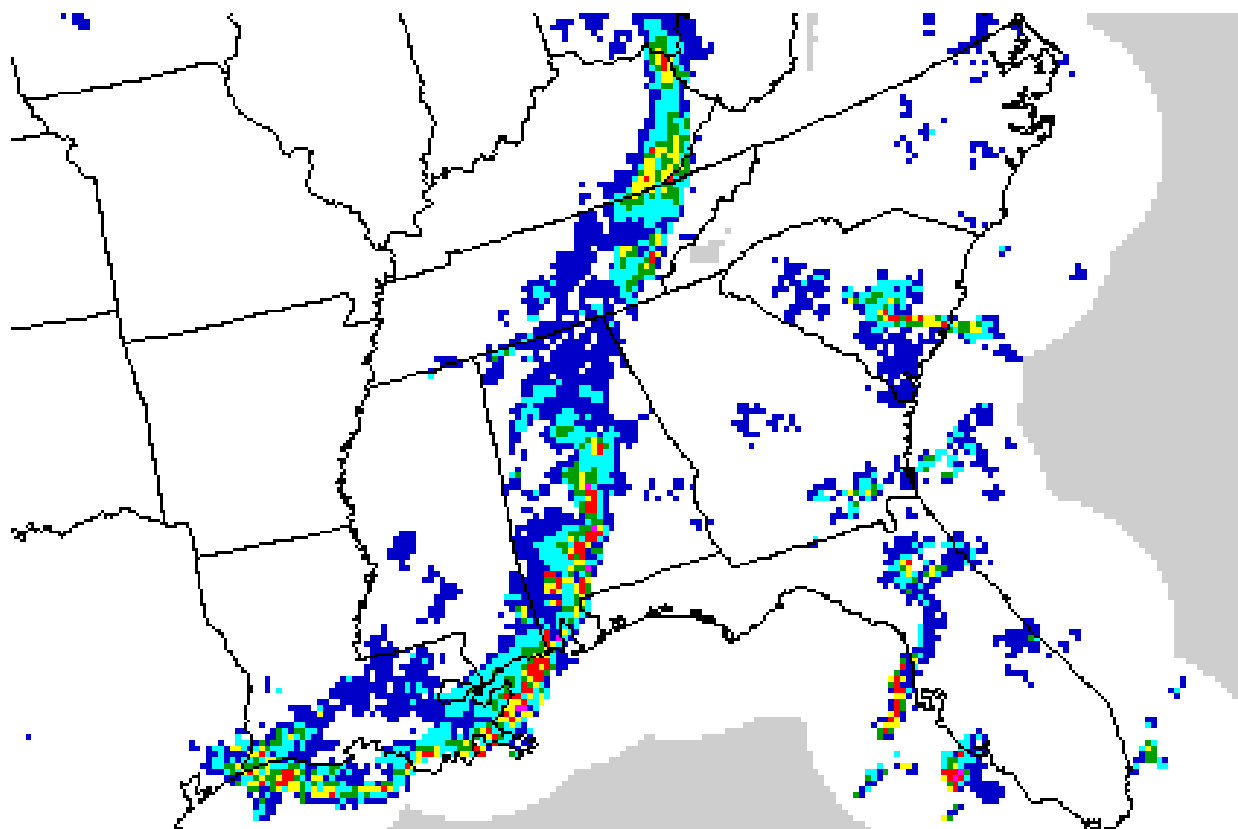


Figure 2. As in Fig. 1, except for subsection covering the southeastern United States.